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Educational initiatives

Curriculum planning in energy engineering education

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ABSTRACT

Curriculum is a key factor in defining programme outcomes. It typically consists of modules and courses, which should be linked together to produce the desired learning outcomes for students. This work aims to explore the practical and theoretical principles of curriculum-centred strategic planning and to inspect how curriculum planning and its implementation are visible in the corresponding teaching structures and student experiences. The research approach used in this paper includes a student survey, teacher interviews and core content analysis. The paper demonstrates that when addressing only a cluster of courses, a relatively simplified approach provides sufficient information for identifying existing strengths and good practices that can be built upon as well as key areas that need further improvement. In addition, the key observations and best practices can also be utilised within any engineering education context.

1. Introduction

Curriculum is a key factor in university teaching. It reflects the university's rules and course content and it defines programme outcomes. Curriculum reform offers an opportunity to make desired changes to the degree programmes. A successful curriculum planning process seems to take time and cooperation between many stakeholders both inside and outside of the university (Gunnarsson, S., 2010; Desha and Hargroves, 2010; Sng, 2008). Many authors have called attention to the need for better interaction between universities and those involved in working life in order to provide industry-relevant competencies (Jackson, 2010; Tynjälä et al., 2003). In connection with successful curriculum planning, a university needs to simultaneously follow its mission and strategy, pass programme quality accreditations, meet the needs of interested parties, be consistent with respect to the outcomes and objectives of its programmes, and, in the European Union (EU), harmonise its education so that it conforms to the Bologna Process directives (Dolence, 2004; Hakula et al., 2013; Sursock and Smidt, 2010).

This paper discusses course-level curriculum planning at Aalto University's Department of Energy Technology. It focuses on a Master's level energy programme that includes five major subjects. In particular, it focuses on the Urban Energy Systems and Energy Economics (UESEE) module and the four courses comprising it. The authors have three primary goals: to identify the coherence of curriculum planning at the module level, to identify applied teaching methods and to increase student-centred learning practices within the module. Their overall goal is to identify best practices and compile recommendations for strategic planning and teaching in the energy engineering degree programme. These best practices and recommendations can be utilised within any engineering education context.

The research methods employed to achieve this goal are as follows: a student survey, semi-structured teacher interviews and core content analysis (Lindblom Ylanne and Hamalainen, 2004). These methods are employed to obtain an in-depth understanding of the pedagogical approaches applied in the teaching and evaluation of the courses that are a part of the module. Afterwards, the paper will discuss the curriculum planning process and best practices based on these results. To limit the scope of this paper, the authors have not included any interviews with representatives of working life. The findings presented in this paper are based on earlier, preparatory work done by the authors (Mälkki and Paatero, 2012, 2013). However, this paper is based on a broader set of data and presents more thorough observations and findings.

2. Background

Many researchers have focused on the strong connection between curricula development and learning outcomes (Batterman

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et al., 2011; Biggs and Tang, 2007; Wong and Cheung, 2009). Curriculum typically consists of modules and courses that are linked together to produce the desired outcomes. When moving towards larger wholes, Dolence (2003, 2004) uses the term 'strategic planning' to refer to the overall design process for curriculum, where each part of the plan is expected to be part of a larger whole that lasts for a longer period of time and includes all of the teaching done as part of the module. He proposes that the planning of teaching and research agendas should reflect new developments in existing fields and emerging areas of inquiry, with closer links between related or complementary fields. He believes that this would entail a more open approach to staff management, evaluation and funding criteria, teaching, curricula and research.

Exploring the issue further, Biggs (1996) has pointed out that the process of enhancing teaching includes teaching and learning activities that achieve the curriculum objectives for the whole system. Adding to this, Levander and Mikkola (2009) have introduced the idea that curriculum consists of interconnected courses along the learning path; as such, curriculum should include educational goals, educational content, working methods and learning outcomes. Furthermore, Edström et al. (2010) have suggested that learning outcomes are the foundation for curriculum planning. The planning process begins by reflecting on the pre-existing learning environment and then identifying the desired changes and outcomes. In a similar manner, strategic curriculum planning reflects national accreditation standards, university rules and programme traditions.

Biggs (2003) argues that a 'constructive alignment' approach is needed to combine all components of the teaching system so that they are properly aligned with one another. He lists curriculum and its intended outcomes, teaching methods and assessment tasks as parts of the teaching system that need to be aligned with learning activities. Segalàs et al. (2010) experimentally verified that students' learning outcomes could be enhanced by community-oriented and constructive learning approaches. Such learning activities could support high-level learning (Mälkki and Paatero, 2012); likewise, Litzinger et al. (2011) believe that effective learning experiences could be better integrated within the systematic curriculum design process. For example, including problem-solving activities, such as problem-based learning (PBL), in the course content could develop learners' understanding of the subject matter and real-life situations (Loyens and Gijbels, 2008; Mälkki et al., 2012; Tynjälä et al., 2003). Additionally, Lansu et al. (2013) have highlighted the need to rethink engineering education as a means of including the professional demands of stakeholders and academic quality standards in the process of curriculum planning.

The ways in which constructivist learning environments and knowledge building promote learning have also been discussed by Loyens and Gijbels (2008). Students' formal and informal skills are formed during their studies when they are attending courses that are a part of the programme. Hence, individual courses play an important role in building knowledge and working life-related competencies.

Levander and Mikkola (2009) have proposed the idea of using core curriculum analysis as a conceptual tool for analysing, describing, sharing and making the degree programmes understandable at the level of individual courses as well as at the level of the whole programme. Aalto University has been developing a computer-aided core curriculum analysis tool to help curriculum planning efforts (Auvinen, 2011). This tool will help teachers determine the learning outcomes for their courses and cooperate with other teachers in the programme.

In addition to core curriculum analysis, student feedback has been utilised when developing curriculum at Aalto University. Since late 2009, it has been mandatory for teachers to collect feedback; the process is automated, whereby students are asked to provide feedback using the same software platform they use for their individual curriculum plans. Mainly quantitative feedback data are collected using standardised or for the most part standardised forms at the end of each course. The forms also have a field for general remarks and opinions, resulting in qualitative feedback data. Richardson (2005) has explored the questionnaires used in North American, Australian and British studies, and he noticed that there is a clear need to collect more student feedback that can be used as research evidence about teaching, learning and assessment. The research-based results provided by such feedback can be used to improve teaching quality, but he warns that it is unlikely that simply collecting the feedback will lead to significant improvements.

The Bologna Process added external pressure to the need for European universities to use learning outcomes as a basis for establishing national qualification frameworks and arrangements for recognising prior learning (Reinalda, 2008; Rauhvargers et al., 2009). The outcomes and educational objectives of a particular programme are also stressed in the EUR-ACE accreditation process. The accreditation process includes the requirements specified in national legislation and by the university-level management system (EUR-ACE, 2008).

The degree reforms prompted by the Bologna Process began in 2005 and resulted in Finnish technical universities adopting a two-level educational system consisting of both a Bachelor's degree and a Master's degree. As a result, energy engineering was divided into two separate and independent parts: namely, the Bachelor's degree and Master's degree programmes. In addition, students now need to complete the Bachelor's level degree before beginning Master's level studies. The first wave of changes in the degree was implemented immediately after the Bologna reform; however, the reforms included mainly reorganising courses and only a limited number of revisions to courses or actual re-planning of courses. The current, more fundamental change includes a full re-evaluation of all of the teaching and course contents. This has implied a need for strategic curriculum planning for both Bachelor's level and Master's degree programmes. The ongoing curriculum reform of the Bachelor's and Master's degree programmes affects the status and role of every course in all of the programmes at Aalto University. Major changes are being made to previously existing courses and curriculum structures. Some of the courses will be discontinued and their content introduced to other, more comprehensive courses. For this reason, it is important to clarify the status and content of the energy courses before the new Master's level degree programme in energy engineering enters into force. To effectively improve the curriculum, it will be necessary to provide a comprehensive analysis of the courses being taught when aligning the existing courses and planning the new reformed curriculum (Eskandari et al., 2007).

In 2012, Aalto University's Master's degree programme in energy engineering (120 ECTS) included 3–4 teaching modules (20 ECTS each), with each module consisting of 3–7 courses. In addition, the programme included 40–60 ECTS of other coursework, including a Master's thesis (30 ECTS). The programme has a total of five specialisation options (major subjects), including Urban Energy Systems and Energy Economics (UESEE).

3. Research methods

To understand and document the current teaching and course planning practices that are a part of Aalto University's energy engineering education, it was important to focus on a module that serves a large number of energy engineering students. In addition, when the curriculum reform of the Bachelor's and Master's degree

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